Ecosystems, Mycologists, and the Geographical Distribution of Fungi in the Central Pacific[1]

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THE CORRESPONDENCE between the geographical distribution of fungi and the peregrinations of mycologists has often been remarked (Ainsworth, 1968). This is neatly illustrated by *Saccobolus glaber* (Pers. per Pers.) Lamb., a cosmopolitan species with Europe as its type locality. Some dried horse dung collected on one of the Tonga islands produced a crop of ascocarps in moist chamber. The collection (67.24) extends the Pacific range slightly, for *S. glaber* is already known from Tahiti through the travels of L. S. Olive (van Brummelen, 1967). Van Brummelen's records show that many of the cited collections have been contributed by mycologists who, by their travels, have amplified the known range of this coprophilous fungus. Seaver's collections, for example, began in Iowa as early as 1905 with subsequent records from New York, Colorado, New Jersey, Bermuda, Trinidad, and Puerto Rico.

Also well documented is the occurrence of the same fungal taxa from widely separated geographical regions but from similar ecosystems, as Anastasiou has noted for the aquatic Hyphomycetales in Hawaii (1964). The following observations for fungi collected and recorded from various habitats in the Hawaiian Islands and the Central Pacific are designed to illustrate the roles which the ecosystem and the distribution of mycologically interested biologists play in the geographical extension of fungus distribution.

MATERIALS AND METHODS

Collections which have provided data for this paper came from a variety of sources. Individual collectors of fungi are acknowledged in the text for their contributions. The soil samples were collected by Louise F. Potter and the senior author except as noted. Collection data are detailed in Table 1. Methods pertinent to the isolation of fungi are indicated in the text.

FUNGI FROM SELECTED ECOSYSTEMS

Soil: Microfungi

Soils from several Pacific areas have produced records of interest for this discussion. A number of these came from a study of Molokai samples. *Allescheria boydii* Shear (imperfect stage, *Monosporium apiospermum* Sacc.), a causative agent of eumycetoma (Emmons, Binford, and Utz, 1970), has been recognized as a common saprobic soil inhabitant in United States, South America, New Zealand, Europe, and recently, Romania (Alteras and Evolceanu, 1969). Cooke (1957) noted its common occurrence in sewage and polluted water. Its recovery, therefore, from a Molokai soil is unusual only because pathogenic fungi were not being preferentially isolated and the isolate extends the known distribution to the Hawaiian Islands. A culture, typical for both phases, developed on sodium caseinate agar (BBL 11626) from soil collected at the edge of a dike bordering a wet taro patch (69.5). Alteras and Evolceanu (1969) remarked that only two records of direct isolation were known. Their Romanian isolate was recovered indirectly by the mouse technique. Subsequently Kurup and Schmitt (1970) reported a direct isolation from soil of a public park in Ohio. Lee and Baker (1972) reported a *Monosporium* isolated from rhizosphere soil of *Rhizophora mangle* L., collected at Heeia mangrove swamp, Oahu. Further study demonstrated the presence of cleistothecia and the identity of the isolate as *Allescheria boydii*.

Microsporum canis Bodin, a zoophilic dermatophyte, was recovered by direct plating of a pasture soil (69.4), grazed by cattle. Isolation

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TABLE 1

COLLECTION DATA

COLLECTION NUMBER	LOCATION AND DESCRIPTION OF SAMPLE	DATE COLLECTED
Hawaii		
63.25	Hawaii, Hawaii Volcanoes National Park, Kipuka Puaulu, lava tube; coll. G. E. Baker	23 November 1963
63.37	Hawaii, Hawaii Volcanoes National Park, Kipuka Puaulu, soil profile, 0.0–5.0 cm; coll. G. E. Baker	23 November 1963
63.38	Hawaii, Hawaii Volcanoes National Park, Kipuka Puaulu, 63.37, soil profile, 5.0–16.0 cm; coll. G. E. Baker	23 November 1963
64.32	Maui, Haleakala Crater, Transect *A*; coll. Malcolm Brown, Jr. (A.2)	3 August 1964
64.35	Maui, Haleakala Crater, Transect *A*; coll. Malcolm Brown, Jr. (A.3)	3 August 1964
64.60	Maui, Haleakala Crater, Transect *C*; coll. Malcolm Brown, Jr.	3 August 1964
64.62	Hawaii, Hawaii Volcanoes National Park, Chain of Craters Road, at mouth of steaming vent, 92° C; coll. G. E. Baker	7 August 1964
64.76	Hawaii, Hawaii Volcanoes National Park, volcanic ash, Kilauea Iki; coll. Malcolm Brown, Jr. (K-I.7)	14 July 1964
64.113	Fresh poi, pressure cooked, Taro Brand, Honolulu Poi Co., Honolulu; isolated by G. E. Baker	21 July 1964
65.36; 65.38–65.42	Hawaii, Mauna Kea, Lake Waiau, elevation 3,970 m, water samples; coll. M. G. Gilmartin	8 July 1965
65.37	Hawaii, Mauna Kea, Lake Waiau, elevation 3,970 m, bottom ooze, 3.0 m; coll. M. G. Gilmartin	8 July 1965
65.43	Hawaii, Mauna Kea, Lake Waiau, elevation 3,970 m, algal mat; coll. M. G. Gilmartin	8 July 1965
65.44	Hawaii, Mauna Kea, Lake Waiau, elevation 3,970 m, bottom ooze, 3.5 m; coll. M. G. Gilmartin	8 July 1965
Society Islands		
65.45	Raiatea, Isle of Ti Paumaua, coconut stand with leaf litter	17 August 1965
65.46	Raiatea, coconut grove adjacent to Bali Hai Hotel	18 August 1965
65.47	Bora Bora, grass-covered roadside shaded by guava shrubs, grasses, and ferns	19 August 1965
65.48	Bora Bora, wet sand beach in front of fale no. 25 at the Bora Bora Hotel	19 August 1965
65.49	Moorea, white sand beach under *Hernandia* sp. trees	23 August 1965
65.50	Moorea, coffee grove at the base of Montué, cultivated soil	23 August 1965
65.51	Moorea, edge of a land-crab hole in a coconut grove adjacent to the Bali Hai Hotel	23 August 1965
65.52	Tahiti, vanilla patch, cultivated soil	26 August 1965
Tonga		
67.22	'Eua, 'Euafo'ou Settlement, Mu'a, elevation 350 ft, front doorstep, upper ¾″ soil; coll. M. L. Bristol, no. 1914	21 July 1967
67.23	'Eua, 'Ohonua, sea level, coarse sand amidst coral rubble at Landing Place; coll. M. L. Bristol, no. 1915	21 July 1967
67.24	'Eua, 'Ohonua, sea level, old horse dung; coll. M. L. Bristol, no. 1916	21 July 1967
67.25	'Eua, 'Ohonua, leafmold and soil from old rubbish heap; coll. M. L. Bristol, no. 1917	21 July 1967
67.26	Tongatapu, Nuku'alofa, Beach House, sea level, backyard soil; coll. M. L. Bristol, no. 1918	22 July 1967
67.27	Tongatapu, Nuku'alofa, Beach House, sea level, sandy loam in hedgerow; coll. M. L. Bristol, no. 1919	22 July 1967
67.28	Tongatapu, Nuku'alofa, Beach House, sea level, damp sandy loam at corner of building; coll. M. L. Bristol, no. 1920	22 July 1967
Hawaii		
68.22	Leeward Islands, French Frigate Shoal, Tern Island, elevation 5 ft, behind living quarters; coll. Derral Herbst, no. 8	1 September 1968
68.32	Leeward Islands, Laysan Island, 200 yd from *Casuarina* tree, in bunchgrass association; coll. Derral Herbst, no. 18	7 September 1968

TABLE 1 (*continued*)

COLLECTION DATA

COLLECTION NUMBER	LOCATION AND DESCRIPTION OF SAMPLE	DATE COLLECTED
68.35	Leeward Islands, Laysan Island, large barren area in southwest quarter of the island; coll. Derral Herbst, no. 21	11 September 1968
69.2	Molokai, cultivated pineapple field off route 46 on back road west of airport	11 November 1969
69.3	Molokai, uncultivated land across the road from 69.2 site	11 November 1969
69.4	East Molokai, Brant Field on route 45, pasture with grazing cattle	11 November 1969
69.5	Molokai, edge of raised dike in wet taro patch, route 45, Thatcher's Diamond T ranch, near Kamalo	11 November 1969
Line Islands		
70.4	Fanning Islands, lagoon shore under coconut tree; coll. E. Alison Kay	9 January 1970
Hawaiian Islands		
71.6	Oahu, Sacred Falls, decaying leaf in stream; coll. F. V. Ranzoni, no. 5	29 September 1971
71.11	Kauai, Lawai, Lawai Valley, Pacific Tropical Botanical Garden, Four House Canyon, streamside in heavy shade of *Hibiscus tiliaceus*; coll. Derral Herbst, T. D. McNeil, and Daniel Omer	8 October 1971
72.12	Kauai, Kawelikoa, horse dung in dry open pasture, elevation 600 ft; coll. Derral Herbst	28 January 1972
72.13	Kauai, Lawai, Pacific Tropical Botanical Garden, Kipukai area, rotting bagasse mulch; coll. Derral Herbst	3 January 1972

of *M. canis* has been recorded previously from two sand beaches on Oahu, Hawaii (Kishimoto and Baker, 1969). The Molokai isolate was obtained on a medium designed by Roth, Orpurt, and Ahearn (1964). A soil isolate is known also from Romania (Beneke and Rogers, 1971).

The plating of other Molokai soil samples was noteworthy for direct isolation of *Rhizophlyctis rosea* (de Bary and Woronin) Fischer, again by use of sodium caseinate agar. Isolates were recovered from two soils: a cultivated pineapple field (69.2) and an uncultivated area across the road from the cultivated field (69.3). The first sample yielded sizable populations of this cosmopolitan chytridiaceous fungus, averaging 54,000 colonies per gm of soil. The count for the uncultivated sample was very much lower. Direct isolation is unusual, for isolation is commonly achieved by baiting. Sparrow (1965) noted that this fungus was the most widespread of the Phycomycetes he isolated in Hawaii. His records were from all the islands except Molokai.

New records for two species of *Mortierella* have accrued from other soil sources. *M. capitata* Marchal was found in soils collected on three of the Society Islands: Isle of Ti Paumaua, Raiatea (65.45); Bora Bora (65.47); and Moorea (65.51). All isolates were recovered on cellulose (sterile filter paper) over sodium caseinate agar or over Emerson's YpSs agar (Difco 0739). According to Zycha and Siepmann (1969), *M. capitata* is known from the stroma of *Xylaria tulasnei* on rabbit dung, Belgium; on mouse dung, England; from forest soil, pH 6.8, India; and soil from Japan. The Society Islands isolates extend the distribution to the tropics where it seems well established in soil.

In the fall of 1970, Dr. A. P. Martinez, associate specialist in Plant Pathology, the University of Hawaii, brought in an unusual fungus in debris taken from the bottom of a commercial hydroponics tank used for tomato cultivation at Waianae, Oahu. It was identified as *Mortierella ambigua* B. S. Mehrotra. Zycha and Siepmann (1969) recorded only the original isolation for this species, an isolation which was made in 1963 from garden soil, Allahabad, India.

Phialophora richardsiae (Nann.) Conant, recognized now as an etiologic agent of phaeosporotrichosis (Emmons, Binford, and Utz, 1970) is known as a saprobe on wood and wood pulp from Sweden and North America (Wang, 1965). Two isolates were noted in Society

Islands soils. One came from Bora Bora (65.47), the other from Moorea (65.51). The Bora Bora isolate compared favorably both morphologically and physiologically with descriptions of *P. richardsiae.* It grew well at 37° C. The second isolate was in morphological agreement but was not checked for growth at 37° C. Admittedly the accurate determination of the taxa of dematiaceous fungi which are causative agents of disease in man is difficult but these isolates agree closely with published accounts for *P. richardsiae.* No claim is made for their pathogenicity.

Three species of *Myrothecium* occurred among the Society Islands samples. All are known from the Central Pacific but in varying frequencies. Least common is *M. striatosporium* Preston, still unrecorded in Hawaii. When Petersen (1960) noted its presence in Moorea soil, he remarked that its known Pacific distribution until then was limited to New Zealand. This species was recovered twice, but only from Moorea soils (65.50 and 65.51). *M. roridum* Tode was represented by isolates from both Bora Bora (65.47) and Moorea (65.49). *M. verrucaria* (Albert. & Schw.) Ditmar occurred in four locations: Raiatea (65.45 and 65.46) and Bora Bora (65.47 and 65.48). Quinn (1968) found only *M. roridum* and *M. verrucaria* in her studies of Tonga soils, the former less frequently than the latter. The same frequency is characteristic of both Hawaiian Islands and Society Islands isolations of these two species.

All three species are found in New Caledonia, according to Huguenin (1966). The latest extension of their Pacific distribution has been provided by Paul H. Dunn who recently (June 1971) isolated all three from sands collected on Eniwetok Atoll, Marshall Islands (personal communication). *M. striatosporium* was found in two areas: the midslope of the beach on the seaward side and on the lagoon side in three zones: supralittoral, low tide line and subtidal. *M. verrucaria* occurred only in the low tide line on the seaward side. *M. roridum* was found more frequently with isolates recovered from the supralittoral zone and the top of the last high tide line on the lagoon side. Not only do the Eniwetok records extend the geographic range of these Myrothecia but they extend the ecological range to marine habitats.

Quinn (1968) made a concentrated effort to increase the number of isolates from Tonga soils to the point of maximum return. Besides using three standard media for dilution plating she used seven selective media, three other methods, and selected temperatures. By these extended operations she was able to isolate 132 species representing 49 genera of fungi from six soils and one dung sample (67.22–67.28). Although Petersen (1960) employed a variety of methods he did not employ the total spectrum for each sample. This may have contributed to his lower return from 10 soils and five dung samples: 25 genera with 67 species. The eight Society Islands soils (Baker and Potter, 65.45–65.52) yielded 80 species distributed among 43 genera (Baker, unpublished data), after plating with two standard media and one selective medium. Only 11 of these fungi were included in Petersen's list. Quinn found Tonga and Tahiti (Petersen's list) shared 17 species; Quinn's list compared to Baker's, showed 27 species in common. Neither Quinn nor Petersen reported any Acrasiales. Baker found two genera: *Dictyostelium* sp., only from Tahiti (65.51), and *Guttulina* sp., which was comparatively common with isolates from Raiatea (65.46), Bora Bora (65.47), Moorea (65.49 and 65.51) and Tahiti (65.52).

Among the interesting isolates common to the Tonga and Society Islands soils was *Diheterospora,* noted for conspicuous muriform aleuriospores, at first hyaline but becoming golden brown. According to Barron (1968) it is not uncommon in soils. Barron summarizes the history of its two species chronologically. *D. chlamydosporia* (Kamyschko) Barron & Onions and *D. catenulata* Kamyschko were originally described in 1962 as terrestrial species from the Leningrad region. Batista and Fonseca noted *D. chlamydosporia* from northeastern Brazil in 1965. Other records include Ceylon, England, New Zealand, British Columbia (Barron and Onions, 1966) and Georgia (Hammill, 1970). In 1966 Dominik and Majchrowicz described a fungus from Guinea, Africa, which Barron (1968) suggested was probably *D. chlamydosporia.*

In the Central Pacific, records have accrued from Tonga, the Society Islands, and Hawaiian Islands. Quinn recovered *D. chlamydosporia* on horsehair bait from two soils, both from the island of Tongatapu (67.27, 67.28). The soils were sandy loams, but one was from a hedgerow and drier. Quinn's isolates were recovered only on horsehair bait. Ajello and Alpert (1972) have noted the same keratinophilic relationship for *D. chlamydosporia* found in soils of Easter Island. Baker has found both species: *D. chlamydosporia* in Society Islands soils (Moorea, 65.50, 65.52) and *D. catenulata* in soils of Hawaii (63.25, 63.37, 63.38). Dunn has recorded *D. catenulata* from a black sand beach on Hawaii (personal communication).

Recently it has been suggested that both these species of *Diheterospora* should be considered *Verticillium chlamydosporium* Goddard (von Arx, 1970). Whether or not such taxonomic combination is accepted, these striking fungi present an interesting and widespread distribution pattern in the Central Pacific.

The distribution of *Microsporum gypseum* (Bodin) Guiart and Grigorakis is extended to Tonga with Quinn's isolate obtained on horsehair bait from soil collected under a front doorstep on the island of 'Eua, Euafo'ou, Mu'a (67.22). A similar extension of distribution can be recorded for *Trichophyton ajelloi* (van Breuseghem) Ajello which Baker recovered from volcanic ash of Kilauea Iki, Hawaii Volcanoes National Park, Hawaii (64.76).

Soil: Macrofungi

Attention became focused on the phalloid fungi of Hawaii through collections of *Aseroë rubra* La Billardier ex Fries. Since the first record in 1965, the number of collections has risen to 12 (Goos, 1970*b*; Baker, unpublished data) from all the Hawaiian Islands except Hawaii. Its occurrence on Kauai was confirmed by a collection made in the Lawai Valley (71.11).

When Goos (1970*b*) reviewed the status of phalloid fungi in Hawaii he noted that *Phallus rubicundus* (Bosc) Fries had not been reported since Cobb's studies (1906). Cobb wrote then that this species was found commonly in cane fields. Goos commented that surely this fungus, widely distributed in Hawaii at one time as well as in other tropical and subtropical regions of the world, must still occur in the Hawaiian Islands. Two recent collections justify this assumption. One is from an open lawn in Honolulu (No. 262, Robert Ueki, 18 November 1971) and the other from Kauai where it was found growing on rotting bagasse mulch (72.13).

A new species of *Clathrus, C. oahuensis,* was collected by J. A. Meeker and W. Stump in 1970 and has been described recently (Dring, Meeker, and Goos, 1971).

In 1966 the late W. Cutting (School of Medicine, University of Hawaii) collected a stalked gasteromycete on the island of Hawaii. It was growing in an open, dry area near the Mauna Kea Hotel (Cutting, 6648). This fungus proved to be *Battarraea digueti* Pat. & Har. The type collection from Baja California, Mexico, was made in 1896. Additional records include Tucson, Arizona; Zacatecas, Mexico; the Gulf of California, Mexico; Hidalgo County, Texas; and the edge of the Mojave Desert at Palmdale, California (Rea, 1942). Consequently this species was considered to be limited to North America (Cunningham, 1942) until it was reported from the Transvaal, South Africa, by Evans (Doidge, 1950), who found it growing on a termite heap. Species of *Battarraea* are usually associated with sand or gravelly soil which would describe the Hawaiian habitat. The Hawaii collection establishes a second record for this species outside the North American continent and the first record for Hawaii and presumably for the Central Pacific area.

Pisolithus tinctorius (Pers.) Coker & Couch, previously unreported for Hawaii, is now recognized as being common in the Hawaiian Islands. Distribution of the species begins, according to Cunningham (1942), with the type collected in Southern Europe and now is extended to North America, where it is common in at least three southern states (South Carolina, Florida, and Alabama), Washington, and Oregon; Africa; East Indies; Australia and Tasmania; and New Zealand. Its habitats are well-drained soil and worn spaces of lawns and pastures (Coker and Couch, 1928), road cuts (Smith, 1951), and thermal region of New Zealand (Cunningham, 1942). To this geographic spread now can be added the first collections in the Hawaiian Islands (R. D. Goos H-125, Forest Reserve, Molokai, no date given; John Porter, Waimano Trail, Oahu, no date given; Lawai Valley, Kauai, collector D. Herbst, July 1971).

Organic Substrata

Filamentous ascosporogenous yeasts as represented by the genera *Endomycopsis* and *Endomyces* characteristically occupy a wide spectrum of habitats, often displaying a predilection for carbohydrate rich substrata (Gäumann and Dodge, 1928; Lodder and Kreger-van Rij, 1952). Sources of *Endomyces* species include slime flux of oak trees, old gills of a mushroom, cold water retting of *Hibiscus cannabinus* L., Java jute (van der Walt, 1959), and most recently a prune processing plant (Macy and Miller, 1971). Their geographical range extends from Europe to the eastern Transvaal to California.

It seems in keeping, therefore, that *Endomyces tetrasperma* Macy and Miller (1971) occurs in the basic Polynesian food, poi, made from starch-rich tubers of taro (*Calocasia esculenta* [L.] Schott.). In the Hawaiian Islands poi is consumed at varying levels of fermentation (Allen and Allen, 1933). Although Allen and Allen specified yeasts as constituents of the microflora in poi, no reference to filamentous species was made. They did comment that there were a number of "contaminants" in poi, derived from the equipment, the water of the factory, or the workers preparing the poi.

This poi strain of *Endomyces tetrasperma* Macy & Miller was first seen by the senior author in 1962 but not isolated. It appeared as white filamentous surface growth at the base of a bag of fresh poi left in the laboratory for 2 to 3 weeks. In July 1964 it was found again by using the same incubation method on fresh poi (Taro Brand, Honolulu Poi Company). This time it was isolated in axenic culture (Baker, 64.113). Subsequently it was distributed for class use at the University of Hawaii where it is highly regarded for its free production of arthrospores, isogametangia, asci, and ascospores (Fig. 1). In 1969 another isolation was achieved by the same technique and again from Taro Brand fresh poi. The fungus seems well established and persistent in this local product.

Macy and Miller (1971), who described *E. tetrasperma* as a new species, obtained their isolate from scrapings of a conveyor belt used in prune processing. There is no doubt that the two isolates, from poi and prune, represent the same fungus. Morphologically they are identical. Physiological data are also in complete correspondence.

Coprophilous Substrata

A single sample of horse dung was collected on Kauai by Derral Herbst in January 1972 for a conspicuous display of stalked ascocarps. These were light-colored, nail-shaped heads supported on darker stalks, emergent from the dung and characteristic of *Poronia oedipus* (Mont.) Mont. (72.12). The perithecia were immature but moist chamber culture encouraged the formation of dark, erumpent spore masses. The collection displays the definitive stipe characters particularly well (Miller, 1942). The base is enlarged and embedded in the substratum; the free upper portion tapers to a slender point of attachment. Measurements are in agreement with Miller's data. *Poronia oedipus* is known from the Caribbean (Waterson, 1947) to the Pacific Ocean (Dennis, 1957). Most recently it has been reported from Malaya (Lim, 1968).

The type species of *Poronia, P. punctata* L. ex Fr., is regarded as primarily a northern hemisphere fungus and *P. oedipus* as more common in the tropics (Gäumann-Dodge, 1928; Miller, 1942). Both species have been recorded from South Africa (Doidge, 1950). Dennis noted in 1968 that *P. punctata* was "evidently abundant in the nineteenth century, now extremely rare but apparently not quite extinct." Since there has been a gap of 66 years between collections of *Phallus rubicundus* in the Hawaiian Islands, there may yet be time for *Poronia punctata* collectors to bring 20th century records into accord with those of the 19th century.

The same dung sample provided records for *Sporomia minima* Auerswald, *Podospora anserina* (Cesati) Niessel, and *Ascobolus immersus* Pers. per Pers. There are *Sporomia minima* records on coprophilous substrata from the Society Islands, Moorea (Petersen, 1960); and possibly New Caledonia (Huguenin, 1966) although the species was not named. From the Hawaiian Islands, including the Leeward group, and Tonga, there also are records without ob-

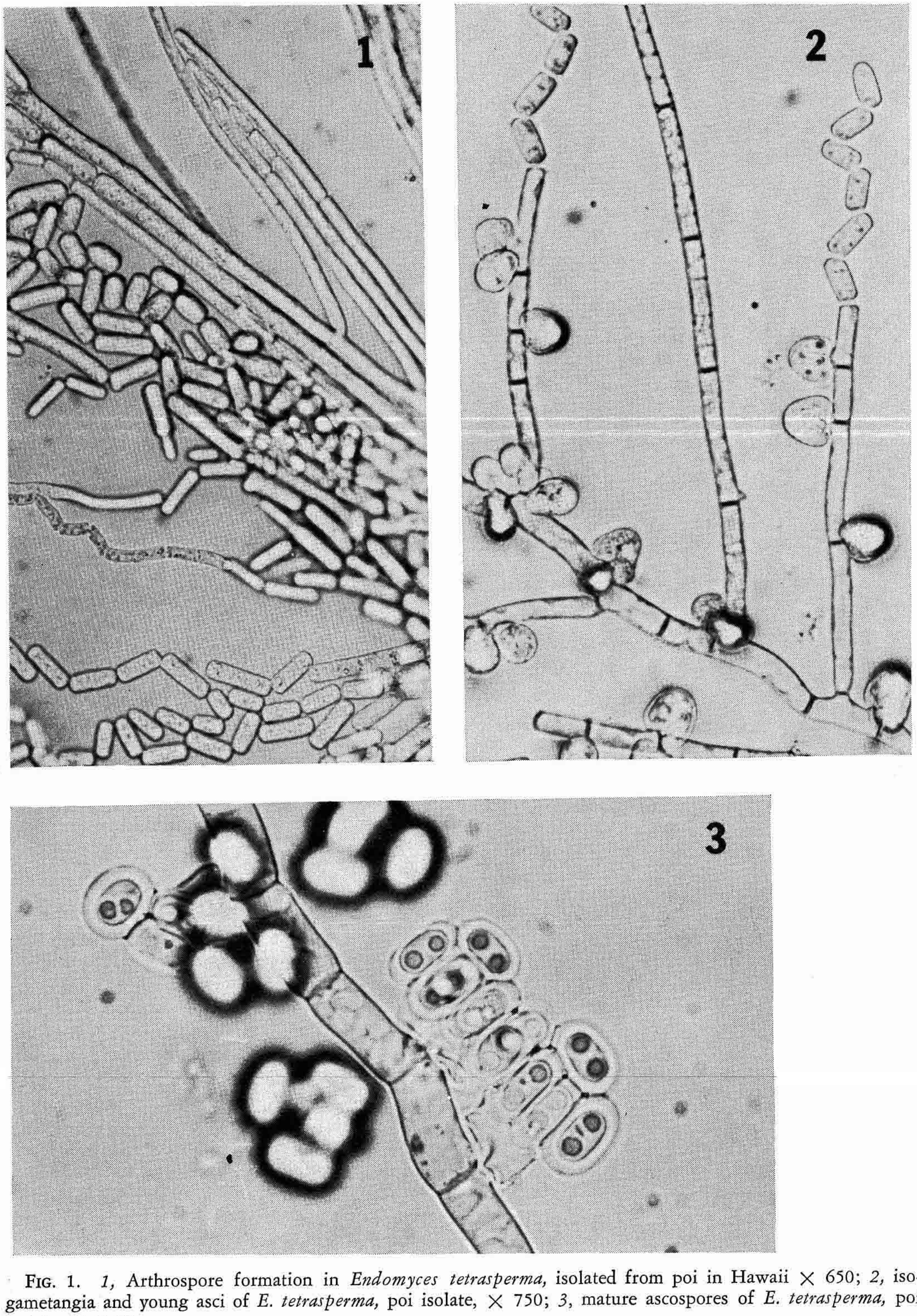

FIG. 1. *1,* Arthrospore formation in *Endomyces tetrasperma,* isolated from poi in Hawaii × 650; *2,* isogametangia and young asci of *E. tetrasperma,* poi isolate, × 750; *3,* mature ascospores of *E. tetrasperma,* poi isolate, × 2,000.

vious coprophilous associations (64.60, 64.62, 64.76, 67.25, 68.32, and 68.35). One isolate was recovered from a Hawaii sample (64.62) taken at a steaming volcanic vent with a temperature of 92° C.

Podospora anserina previously was recorded on horse dung from Tonga (67.24, isolated by R. D. Goos) and from Oahu (R. D. Goos, no. 369).

There are several Hawaiian records for *Ascobolus*. *A. immersus* was collected on Hawaii in 1962 (van Brummelen, 1967); *Ascobolus* sp. is recorded for two collections, one on pig dung, Hawaii (R. D. Goos) and the other without any collection data. *A. hawaiiensis* Brumm. rests on its original collection from sheep dung, Hawaii (van Brummelen, 1967).

Mortierella rostafinskii Brefeld is another coprophilous fungus with a notable time gap between first and second collections. Kuhlman and Hodges (1972) have reported recent collections, one from Georgia and one from Hawaii. The Hawaiian isolation was made by R. D. Goos from gecko dung collected on Oahu (Goos, personal communication).

The Phylloplane

In 1922 F. L. Stevens spent several months collecting fungi in Hawaii, covering all the islands. This resulted in an extensive account of fungi in Hawaii (Stevens, 1925). His attention was directed almost exclusively to leaf parasites, but even so he overlooked the genus *Atichia* Flotow, a striking oversight since the genus is ubiquitous on leaves throughout the islands. All but one of the eight recognized species have been found on Oahu (J. A. Meeker, unpublished data). This exception is balanced by at least one undescribed species. The genus *Atichia* is mainly tropical, but the type was described from the Swiss Alps, where it was growing on pine needles.

The history and synonomy of the Atichias is detailed by Müller and von Arx (1962), beginning with its designation in 1825 as a lichen, an error which persisted in the literature for some 30 years. By 1850 Flotow had established the accepted generic name but the position and nature of the genus remained obscure until the researches of Raciborski in Java some 50 years later. Raciborski recognized several species, all common. Since then mycological attention has shown that these fungi occur significantly in New Zealand (Fraser, 1936), Australia (Fisher, 1940), Brazil (Batista, 1957), and Dominica, B.W.I. (Farr, 1969). The conspicuous absence of the genus from Central America, Africa, and India, appears to coincide with the absence of an observant mycologist, as noted by Dennis (1968).

Forest Litter, Humus

Fungi growing on the ground or on fallen leaves are poorly represented in Hawaiian records, but this is due largely to a lack of specialists concerned with this ecosystem. Ascomycetes occurring in these habitats have received perhaps the least attention. The group is obviously represented in Hawaii. A species of *Dasyscyphus* is collected so often by students that its ubiquity results in a form of ennui when encountered.

In March 1971 an ascocarp of *Morchella vulgaris* (Pers.) Boud. was found growing on the ground as a solitary specimen (Hawaii: Robert Ueki, no. 72, Manoa Falls, upper Manoa Valley, Oahu, 14 March 1971). This is the first collection of a *Morchella* in the Hawaiian Islands. Many of the fleshy fungi which occur in the islands are notably ephemeral. If true for morels, this record may merely represent the timely coincidence of collector and specimen, not the rarity of the fungus. The specimen has been preserved in formalin-acetic acid-alcohol.

The published list of agarics comprises less than a dozen genera. Accruing records and experience in the field indicate that many more have been seen. Ueki's records extend this number to some 40 more (personal communication). Species of *Mycena, Marasmius,* and *Hygrophorus,* easily recognized in the field where they appear frequently, are good examples of fungi which have escaped detection only as long as interest was not focused on them. The record for other Basidiomycetes parallels the agaric situation. Clavarioid fungi, once thought absent, now are represented by two species of *Pistillaria: P. micans* Fr. and *P. rhodocionides* Corner, in addition to *Chaetotyphyla hyalina* (Jungh.) Corner, already recorded for Hawaii (Baker, 1968). All are in axenic culture and have been induced to fruit on agar media. Another clavarioid species (71.6) has recently been found. F. V. Ranzoni, who was isolating aquatic Hyphomycetes in Hawaii during the fall of 1971, contributed an isolate of an unidentified basidiomycete. On 2-percent malt agar it produced incipient basidiocarps, not identifiable but suggestively clavarioid. A subculture on the same agar was unintentionally allowed to dehydrate. This induced a crop of handsome *Physalacria* basidiocarps. They probably represent a new species. The source of this fungus was a decomposing leaf collected in an Oahu stream (Ranzoni, personal communication).

Aquatic Habitats

Lake Waiau (Fig. 2) on the summit of Mauna Kea, the island of Hawaii, is unusual as an alpine lake in tropical latitudes. It was described by Gregory and Wentworth (1937) as a perennial body of water, part of the drainage system of the summit of Mauna Kea. It lies above timberline at an elevation of 3,970 m where night temperatures fall below freezing so that marginal areas are ice-covered even in summer months. Some very general observations about the flora and fauna of Mauna Kea were made by Lyon as reported by Gregory and Wentworth (1937). The only fungus mentioned was *Achlya* sp. on *Daphnia* in the lake. Hartt and Neal (1940) made a detailed study of the vegetation of Lake Waiau with incidental reference to microorganisms, but no actual sampling of the lake was included. A study of the bottom sediments in this alpine lake was made by Woodcock, Rubin, and Duce in 1966. They considered Lake Waiau, by virtue of its position, to be a natural trap for airborne and waterborne particles.

In the summer of 1965 water and bottom samples were available for microbiological analysis (65.36–65.44). According to M. G. Gilmartin (Hopkins Marine Station, unpublished) who made the collections, the lake covers an area of 1.97 acres with maximum depth of 3.5 m. Currently there are construction plans for the area which will disturb the microbial ecosys-

FIG. 2. Lake Waiau, Mauna Kea, island of Hawaii, elevation 3,970 m. Photograph by Agatin T. Abbott, Hawaii Institute of Geophysics, University of Hawaii.

tem significantly. Consequently, it seems important that the results of the 1965 study be on record.

Comparison of the Lake Waiau mycota with mycota of similar aquatic habitats previously studied in Montana revealed interesting correspondence between the taxa represented in these two widely divergent geographic locations. The Montana habitats included five small ponds, two small oligotrophic lakes, and one man-made reservoir. All are located in the Mission Valley of the Flathead basin of northwestern Montana. Surface areas varied from 0.0008 acres to 0.28 acres for the ponds; from 2.8 to 24.2 acres for the two lakes; and the reservoir at capacity has a surface area over 14,000 acres. Both Lake Waiau and the Montana habitats are alkaline. Lake Waiau had readings of pH 8.1 to 8.3 in July 1965. The Montana group showed some seasonal variation of pH, between 8.0 and 9.7 as minimum and maximum readings. Woodcock, Rubin, and Duce (1966) noted that the temperature of the deeper sediments of Lake Waiau is approximately 6° C all year. The Montana sites are subject to freezing the better part of the year.

Both water and bottom samples were handled by standard quantitative plating techniques (Johnson et al., 1959) using sodium caseinate agar (BBL 11626) supplemented by use of Cooke's rose bengal agar (Difco 0703) and a medium recommended by Roth, Orpurt, and Ahearn (1964). A total of 70 fungi (exclusive of yeasts and nonsporulating mycelium) was recovered from all the samples: 56 from Montana and 28 from Lake Waiau, of which 14 were common to both areas (Table 2). Among the remaining 14 Lake Waiau taxa were four species known from other aquatic habitats in Montana (Table 2).

The distribution of Montana isolates between water and bottom mud was about equal but from Lake Waiau the number of water isolates, 21, far exceeded those associated with the algal mat which covers the bottom of the lake and those in the bottom sediments. This is not the usual relationship between water and bottom isolates and may be explained in part by a remark in Woodcock, Rubin, and Duce (1966) that Lake Waiau serves as a trap for airborne and waterborne particles. The algal mat may reduce the oxygen level in the bottom sediments which are volcanic ash with low organic content, both conditions probably unfavorable to fungal growth.

Some of the individual isolates from Lake

TABLE 2

FUNGI COMMON TO MONTANA PONDS AND LAKE WAIAU, HAWAII

FUNGI	NUMBER OF ISOLATIONS: MONTANA WATER	MONTANA MUD	LAKE WAIAU WATER	LAKE WAIAU ALGAL MAT	LAKE WAIAU BOTTOM SEDIMENTS
Emericellopsis terricola van Beyma	4	2	1	0	1
Phoma glomerata (Corda) Wollenw. & Hochapfel	18	5	0	1	0
Pyrenochaeta decipiens Marchal	6	0	2	0	0
Aspergillus niger van Tieghem	1	7	1	0	0
Aureobasidium pullulans (de Bary) Arnaud	12	16	1	1	0
Cephalosporium curtipes Sacc.	6	8	1	0	0
Cephalosporium salmosynnematum Roberts	2	1	1	0	0
Geotrichum candidum Link	18	21	0	1	0
Paecilomyces varioti Bainier	8	3	1	0	0
Penicillium fellutaneum Biourge	12	18	1	0	0
Spicaria violacea Abbott	2	0	1	0	0
Trichoderma album Preuss	7	11	0	0	1
Trichoderma lignorum (Tode) Harz	4	5	0	1	0
Trichoderma viride Pers.	14	12	4	1	1
Yeasts	5	4	0	1	0
Nonsporulating mycelium	12	1	0	1	0

Waiau are worthy of remark (Table 3). *Emericellopsis terricola* van Beyma is a first record for Hawaii. Species of *Emericellopsis* are recognized as soil inhabitants, particularly moist soils (Grosklags and Swift, 1957; Durrell, 1959). *E. terricola* was found frequently in such ecosystems in Montana where it was recorded once from water and 10 times from bottom muds of Flathead, Swan, and Rogers lakes, as well as from the bottom mud of two ponds and water of the three other ponds in the Mission Valley. Its occurrence in both water and bottom sediments of Lake Waiau suggests that the Montana and Hawaii habitats are similarly suitable for its establishment. The year-round bottom temperature of Flathead Lake is approximately 5° C, compared to the 6° C temperature of Lake Waiau. In Montana *E. terricola* was isolated 4 out of 6 years from Flathead Lake bottom mud. It would be interesting to check on its persistence in Lake Waiau. Other isolates in common to both regions, e.g., *Aureobasidium pullulans* and *Geotrichum candidum*, are particularly well known for wide distribution in many habitats (Roth, Orpurt, and Ahearn, 1964; Barron, 1968).

The quantitative and qualitative differences between the continental and island fungus populations probably are ascribable in part to sampling, the data being definitely overweighted in favor of Montana where sampling was carried on several years. Although 14 fungi are common to both areas, 10 others found only in Lake Waiau were not recorded over a 10-year sampling period in Montana (Table 3). Yet several of these taxa—*Oidiodendron flavum, Periconia cookei, Aspergillus flavipes, Penicillium decumbens* and *Nigrospora sphaerica*—are frequently found in soils of Hawaii, other Central Pacific areas, and also in temperate regions. *N. sphaerica, Periconia cookei, Aspergillus flavipes,* and *Penicillium decumbens* have been noted as components of the phylloplane on the island of Hawaii (Marsh, 1966) and as air spora on Oahu (Oren and Baker, 1970; Baker, unpublished data).

Sparrow (1965), reporting the results of a survey he made in 1963 for *Physoderma* and other zoosporic Phycomycetes in the Hawaiian Islands, concluded that representatives of this genus and several others were recognizable as the same species known from continental land masses of both eastern and western hemispheres. He suggested that this group of fungi moved into the Hawaiian Islands from older continental land masses, remaining virtually unchanged in contrast to the vascular plants which have evolved to a highly endemic flora. If more

TABLE 3

FUNGI ISOLATED FROM LAKE WAIAU, HAWAII, BUT NOT RECORDED FROM MONTANA PONDS

FUNGI	NUMBER OF ISOLATIONS		
	WATER (65.36–65.42)*	ALGAL MAT (65.43)	BOTTOM SEDIMENTS (65.44)
Circinella rigida A. Smith	1	0	0
Mucor sp.†	1	0	0
Aspergillus flavipes (Bain. & Sart.) Thom & Church	1	1	0
Monilia grisea Daszewska	1	0	0
Oidiodendron flavum Szilvinyi	1	0	0
Penicillium decumbens Thom	1	0	0
Scopulariopsis brevicaulis Bainier†	1	0	0
Scopulariopsis fimicola (Cost. & Matr.) Vuill.	1	0	0
Bispora sp.	1	0	0
Cladosporium avellaneum de Vries	1	0	0
Nigrospora sphaerica (Sacc.) Mason	1	0	0
Phialophora fastigata (Lagerberg. & Melin) Conant†	1	0	0
Torula herbarum Pers.†	1	1	0
Periconia cookei Mason & M. B. Ellis	1	0	0

* See Table 1 for data on collection numbers.

† Known from sources in Montana other than ponds.

than 50 percent of the Lake Waiau isolates are known from similar habitats in Montana and other continental areas, it follows that the Lake Waiau data support Sparrow's comment that the mycota in Hawaii comprise essentially known continental species. Anastasiou's studies (1964) also support Sparrow's thesis, as his isolates of aquatic Hyphomycetales from streams on Kauai were all known continental species except one, designated a new species. New species do not necessarily equate to endemic species. The data from Sparrow, Anastasiou, and Lake Waiau point up the ecosystem as a common factor in geographic distribution. Kohlmeyer (1969) made similar observations for fungi associated with mangroves in Hawaii (1964). Lee and Baker (1972), in a study of fungi in mangrove swamp soil, noted that the microfungal populations in soil of the Heeia mangrove swamp on Oahu, Hawaii, showed correspondence with mangrove soil populations reported from East Africa and India. The evidence, therefore, supports agreement among fungal communities which occur in comparable ecological situations.

Although the coincidence of fungus and collector is important in extending geographical distribution, the ecosystem is also a major factor. However, the adaptability of fungi to a wide range of habitats should not be unexpected. *Emericellopsis*, represented now by 11 species, was recently reviewed by Davidson and Christensen (1971) when they described a species from saline soils in Wyoming. Apparently most species have a predilection for soils which are continuously or periodically wet. Geographically they are recorded from Europe, Africa, North America, India, Australia (Davidson and Christensen, 1971), Japan (Tubaki, 1969), and the Central Pacific (Baker; Dunn; Lee; unpublished data). In Montana *E. terricola* and *E. humicola* were commonly present in cool aquatic habitats, both water and bottom sediments, with alkalinity as high as 9.7 (Baker, unpublished data). The *E. terricola* habitat in Hawaii resembles those of Montana.

To soil and freshwater habitats of cool temperatures for *Emericellopsis* must be added marine habitats, both cool and warm. Tubaki (1969) found two species in marine muds where *E. humicola* was particularly abundant in February. He noted that these records were the first from marine environments but *E. minima* is known from saline coastal mud (Stolk, 1955) and estuarine sediments (Borut and Johnson, 1962). Recently Dunn has extended the geographical and ecological range of the genus with isolates from Eniwetok Atoll, Marshall Islands. He recovered *E. humicola* from beach sand in the tidal range and from foam of a tide pool on the seaward side. The pH readings were 7.8 and 8.5, respectively; sand and water temperatures were 33° to 34° C. Earlier B. K. H. Lee reported an unnamed species of *Emericellopsis* in sand of Fanning Island, one of the Line Islands (70.4, personal communication).

The habitat range, therefore, must be extended to include marine substrata, both cold and warm, with recorded pH levels as high as 8.5. The occurrence of fungus strains adapted to the spectrum of situations now known for *E. humicola* is not unlikely. Manandhar and Apinis (1971) have presented interesting data on temperature responses of 37 strains of *Monascus*. *M. purpureus* was represented in the study by eight isolates from varied geographic locations (Great Britain, Ghana, and Nigeria) which reflected very wide differences in growth rates and reproduction in relation to temperature. Gray, Pinto, and Pathak (1963) have demonstrated the ease with which many fungi grow in either freshwater or seawater.

From the foregoing observations it is apparent that fungi of known frequent and infrequent distribution in the world are becoming increasingly well represented in the Central Pacific area with a striking correlation between mycologists and their geographic distribution. Prior to 1963, publications on fungi of this area were relatively few (Baker, 1964). As mycological studies have increased in Hawaii, a very extensive listing for soil fungi, the phylloplane fungi, air spora, and marine mycota has been accumulating. However, these programs have neglected other important ecosystems. When R. D. Goos was with the group from 1968 to 1970, his interest in lignicolous species expanded the records of known dematiaceous fungi dramatically and also added the new genus *Mycoenterolobium* Goos with its interesting species *platysporum* (Goos, 1970*a*). Among Goos' isolates in Hawaii was *Wiesneriomyces* *javanicus* Koord. (Baker and Goos, 1972), a monotypic genus. Its distribution pattern now goes from the first recording in Java, 1907, to India, 1951; New Caledonia, 1966; Panama, 1967; and to Hawaii, 1968, the last two records being the result of Goos' peregrinations. Another monotypic genus, *Listeromyces,* has had its distribution pattern extended from Java to Hawaii by Goos (1971), who noted that *L. insignis* Penzig & Sacc. has not been reported since its initial collection in 1897, followed by the description published in 1901.

The opportunities for the study of fungi in the Central Pacific are still unlimited. Although recent contributions exceed those of previous decades, much more needs to be done in order to make a fair evaluation of the fungi—their habitats and correlated distribution—in this part of the world.

SUMMARY

The dependence of fungi in geographic distribution upon mycologically interested collectors is illustrated by new or extended records for the Hawaiian Islands, Tonga, the Line Islands, the Society Islands, and the Marshall Islands. The records include microfungi and macrofungi from soil, organic substrata, forest litter, aquatic habitats, and the phylloplane. The new records are discussed in terms of the known distribution of the taxa and their establishment in given ecosystems.

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